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DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-8757

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

BLIND GRID SCORING RECORD NO. 141

SITE LOCATION:
ABERDEEN PROVING GROUND

DEMONSTRATOR:
U.S. ARMY CORPS OF ENGINEERS
ENGINEERING RESEARCH AND
DEVELOPMENT CENTER
3909 HALLS FERRY ROAD
VICKSBURG, MS 39180-6199

TECHNOLOGY TYPE/PLATFORM:
STANDARD GEM-3/PUSHCART

PREPARED BY:
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Prepared for:
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14. ABSTRACT
This scoring record document the efforts of U.S. Army Corps of Engineers Engineering Research and Development Center to detect and discriminate inert unexploded ordnance (UXO) utilizing the APG Standardized UXO Technology Demonstration Site Blind Grid. The scoring record was written by Larry Overbay utilizing methodology coordinated with the Standardized UXO Technology Demonstration Site Program Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Research and Development Program, the Institute for Defense Analysis, the U.S. Army Environmental Center, and the U.S. Army Aberdeen Test Center. Requests for this document must be referred to Commander, AEC, ATTN: SFIM-AEC-PCT.

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (AEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that vary targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e., that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection (P_d^{res}).

(2) Probability of False Positive (P_{fp}^{res}).

(3) Background Alarm Rate (BAR^{res}) or Probability of Background Alarm (P_{BA}^{res}).

b. Discrimination Stage ROC curves:

(1) Probability of Detection (P_d^{disc}).

(2) Probability of False Positive (P_{fp}^{disc}).

(3) Background Alarm Rate (BAR^{disc}) or Probability of Background Alarm (P_{BA}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate (R_{fp}).

(3) Background Alarm Rejection Rate (R_{BA}).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time, and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert ordnance items having properties that differ from those in the set of standardized targets.

TABLE 1. INERT ORDNANCE TARGETS

Standard Type	Nonstandard (NS)
20-mm Projectile M55	20-mm Projectile M55
	20-mm Projectile M97
40-mm Grenades M385	40-mm Grenades M385
40-mm Projectile MKII Bodies	40-mm Projectile M813
BDU-28 Submunition	
BLU-26 Submunition	
M42 Submunition	
57-mm Projectile APC M86	
60-mm Mortar M49A3	60-mm Mortar (JPG)
	60-mm Mortar M49
2.75-inch Rocket M230	2.75-inch Rocket M230
	2.75-inch Rocket XM229
MK 118 ROCKEYE	
81-mm Mortar M374	81-mm Mortar (JPG)
	81-mm Mortar M374
105-mm Heat Rounds M456	
105-mm Projectile M60	105-mm Projectile M60
155-mm Projectile M483A1	155-mm Projectile M483A
	500-lb Bomb

JPG = Jefferson Proving Ground.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC: Jose Llopis
601-634-3164
Jose.L.Llopis@erdc.usace.army.mil

Address: U.S. Army Corps of Engineers Engineering Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

2.1.2 System Description (Provided by Demonstrator)

The second generation GEM-3 system (acquired 1999) is able to collect multiple channels of complex frequency domain electromagnetic induction (EMI) data over a wide range of audio frequencies (30 Hz to 21 kHz). The system is a wheeled pushcart with a 40-cm sensor head, a mounted electronics console, and a user interface. A real-time kinematic (RTK) global positioning system (GPS) is used to collect positioning data for the sensor head that is saved separate from the GEM-3 data file. The sensor head consists of three coils. The primary transmitter coil is the outer coil in the sensor head. The receiver coil is the inner coil in the sensor head. The bucking transmitter coil is the middle coil in the sensor head. The current in the bucking coil flows in the opposite direction of the current in the primary transmitter coil. This suppresses the dipole moment on the receiver coil that is directly from the primary transmitter coil. The electronics console contains the multifrequency current waveform generator, the analog to digital (A/D) converter receiver electronics, the digital signal processor, and the power management module. The user interface utilizes a custom display system. The display system has three command buttons with an liquid crystal display (LCD). This system is used for data logging and allows for real-time control of the system. The display also allows for real-time display of a single frequency of the data collected. The RTK GPS requires a base station to be set up at a suitable reference point for radio communication with the mobile unit on the GEM-3 system. The GEM-3 system's acquisition of multifrequency data allows for performing what Geophex Ltd., the developer of the system, calls Electromagnetic Induction Spectroscopy (EMIS) on buried objects. EMIS provides a method to discriminate UXO targets from natural and manmade clutter objects by means of their unique, complex (inphase and quadrature) frequency responses.

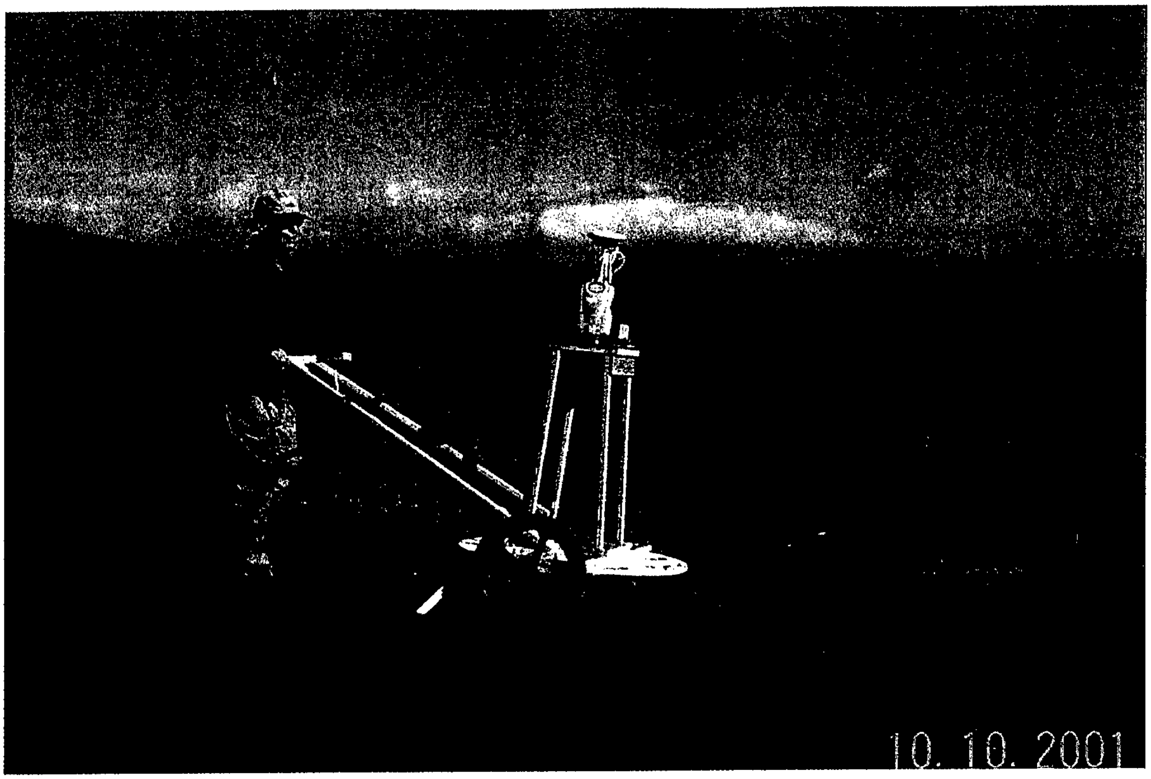

Figure 1. Demonstrator's system (standard GEM-3 pushcart).

2.1.3 Data Processing Description (Provided by Demonstrator)

The GEM-3 data acquired at the test site was processed using a combination of ERDC-developed programs and Geosoft's Oasis Montaj. First, basic data corrections such as background subtraction and time-synchronization between the sensor data and GPS data were performed. The raw data, after these basic corrections, were submitted in Geosoft XYZ format. Two Response Stage submissions were made within 30 days. One was based on a threshold applied to the total magnitude of the sensor inphase and quadrature response for all frequencies. The second was based on interactive histogram analysis of the data. Data from each of these detection schemes were used by the target discrimination algorithm to generate separate Discrimination Stage submissions. The discrimination algorithm compares sensor data collected near each detected anomaly with calibration data acquired over the target types of interest at the beginning of the data collection.

One of ERDC's primary objectives for this data acquisition was to get high quality data to further our modeling and analysis research. ERDC plans to make further data submissions using other detection and discrimination algorithms on this same dataset, alone and in combination with data from other sensors.

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook (app E, ref 1). These submitted data are not included in this report in order to protect ground truth information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (Provided by Demonstrator)

Overview of QC. The operators performed three levels of QC checks: the first day of the project, the beginning of the day, and whenever there was an equipment change (i.e., batteries, data dump, etc.). The first day of the project, the operators laid out a 10-meter long line oriented North South with a ferrite bar at the center. This line was well marked and used each time the instrument was tested and positioned. The operators tested for instrument response over the ferrite bar, and performed position and latency checks. The operators walked the line slowly in two directions and then backed the cart up until it was centered on the ferrite bar. This set the location of the ferrite bar as well as the instrument response, which was referenced every time the operators checked the equipment.

Each morning the operators performed functional equipment checks. The operators visually inspected all equipment for damage. They then powered up the equipment. The operators then performed static and instrument response tests to ensure that the data were stable when the instrument was in a static position over a marked location. These tests were performed after the instrument had sufficient time to warm up.

Overview of Quality Assurance (QA). QA was the responsibility of the project lead. The project lead ensured that test data was inspected and recorded each day using a known target (e.g., ferrite bar) with the GEM-3 sensors, and a reference position with the RTK GPS. Geo-referenced data sets were inspected at the end of the day for GEM-3 data quality and navigation integrity (reasonableness criteria).

Data analysis was performed each day. This analysis included inspection of the data for inconsistencies (bad data and errors). The RTK GPS data was inspected to ensure good coverage and limited dropouts. If the data showed the sensor or electronics were not taking good data or the RTK GPS dropouts were too numerous for data analysis or good coverage; that section was flagged for a resurvey.

2.1.6 Additional Records

Record(s) by this vendor can be accessed via the Internet as MS Word files at www.uxotestsites.org.

2.2 APG SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area of APG. The Aberdeen Area of APG is located approximately 30 miles northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods, and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

ERDC conducted a site-specific analysis in May of 2002 (ref 3). The results basically matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15- and 30-percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is included in Table 2.

TABLE 2. TEST SITE AREAS

Area	Description
Calibration Grid	Contains 14 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration.
Blind Grid	Contains 400 grid cells in a 0.2-hectare (0.5 acre) site. The center of each grid cell contains ordnance, clutter or nothing.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES (8 TO 12 SEPTEMBER 2003)

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site are summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	Number of Hours
Calibration Lanes	8.41
Blind Grid	12.33

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An ATC weather station located approximately 2 miles west of the test site was used to record average temperature and precipitation on an hourly basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 through 1700 hours while the precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2003	Average Temperature, °F	Total Daily Precipitation, in.
September 8	75.9	0.00
September 9	72.3	0.00
September 10	71.7	0.00
September 11	76.1	0.00
September 12	65.1	0.55

3.3.2 Field Conditions

ERDC surveyed the Blind Grid on 11 and 12 September. The Calibration Lane and Blind Grid had several muddy areas due to rain prior to testing, and were extremely wet on 12 September because of rain.

3.3.3 Soil Moisture

Five soil probes were placed at various locations of the site to capture soil moisture data: wet, wooded, open, areas, calibration lanes, and blind grid/moguls. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil layers (0 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. A crew of four people took 3 hours and 15 minutes to perform the initial setup and mobilization. Daily equipment preparation took 30 minutes. Daily start/stop activities totaled 1 hour and for the Blind Test Grid.

3.4.2 Calibration

ERDC collected data in the Calibration Lane on 9 and 10 September. ERDC spent 4 hours and 30 minutes collecting data in the calibration lanes. No calibration activities were conducted in the Blind Grid.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, Demonstration Site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to Demonstration Site issues. Demonstration Site issues, while noted in the Daily Log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are not discussed either.

3.4.3.1 Equipment/data checks, maintenance. Equipment/data checks and maintenance activities did not account for any site usage time while surveying in the Blind Grid.

3.4.3.2 Equipment failure or repair. ERDC had a bad cable connection and had to solder it on three different occasions. Repair of the cable connection represented a total of 6 hours and 45 minutes of downtime.

3.4.3.3 Weather. The weather was sunny and warm for most of the survey. There were small areas of standing water and mud in the Blind Grid as well as the Calibration Lane. On the last afternoon of the survey some heavy rain fell making conditions difficult.

3.4.4 Data Collection

The demonstrator spent 1 hour and 55 minutes collecting data in the Blind Grid. This time excluded break/lunch and downtimes described in section 3.4.3.

3.4.5 <u>Demobilization</u>

The demobilization time for the pushcart took 1 hour. The demobilization was completed by four people.

3.5 PROCESSING TIME

ERDC submitted the raw data from demonstration activities on the last day of the demonstration, as required. The scoring submission data was also provided within the required 30-day timeframe.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Supervisor: Jay Bennett-ACE-ERDC
Data Analyst: John Morgan-Alion
Field Survey: Morris Fields-Alion
Field Survey: Jose Llopis-ACE-ERDC

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

ERDC began surveying the Blind Grid in the northeast corner and continued in a north/south direction. ERDC surveyed the Blind Grid in a linear fashion.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D.

Two issues were encountered: On four occasions a bolt sheared off the wheel of the cart and was replaced; and a bad cable connection with the GEM-3 was soldered on three different occasions. The problem with the cable connection was finally rectified. Because of problems with the wheel, ERDC personnel decided to carry the cart and the survey was completed.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive. Figure 2 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

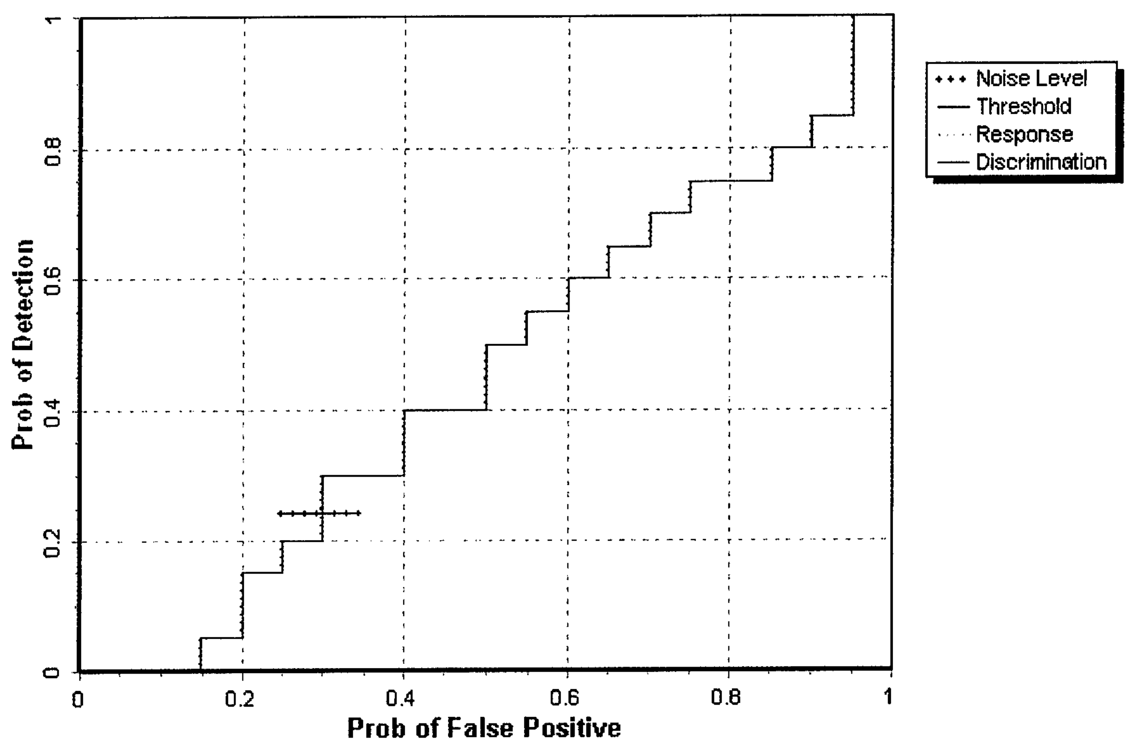

Figure 2. GEM-3 blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

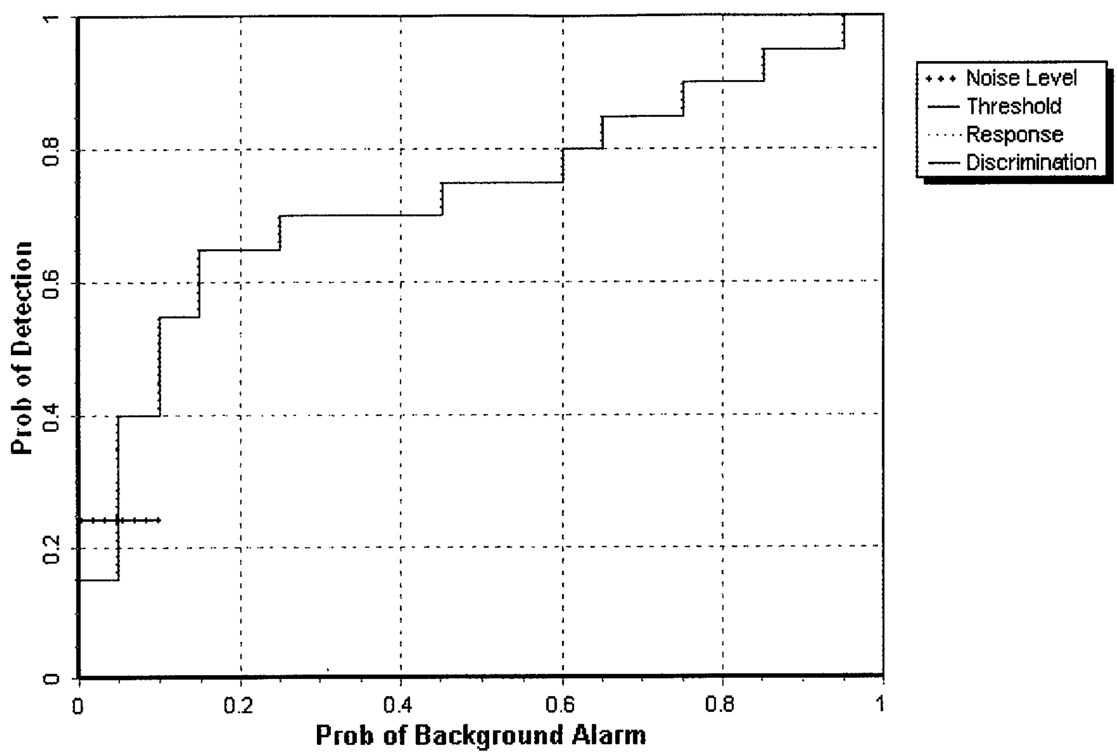

Figure 3. GEM-3 blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 4 shows the probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of false positive when only targets larger than 20 mm are scored. Figure 5 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

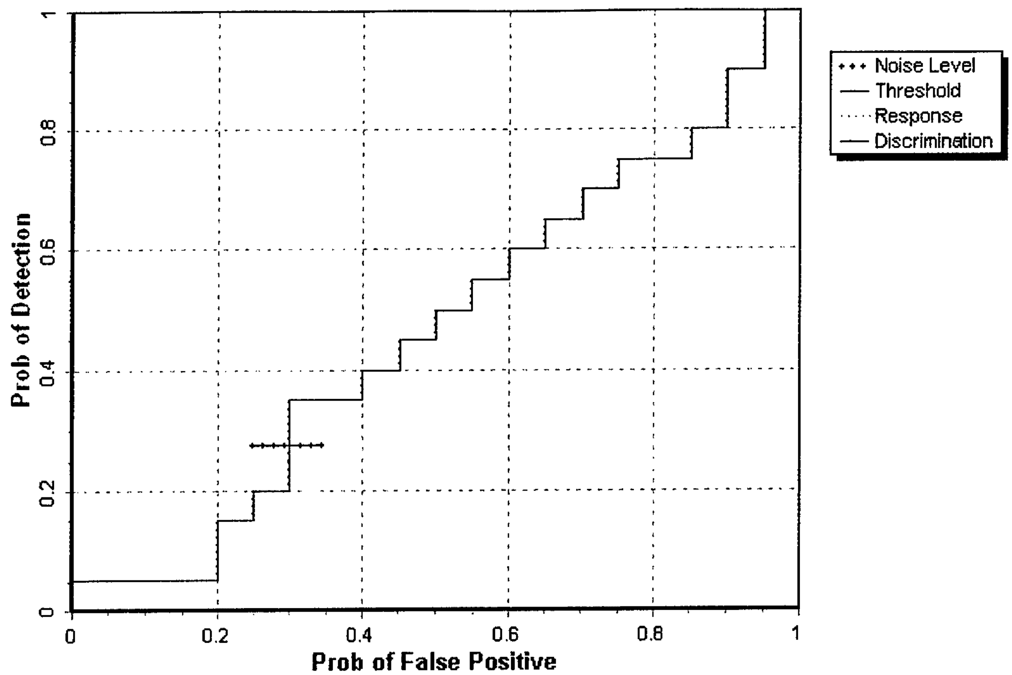

Figure 4. GEM-3 blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20 mm.

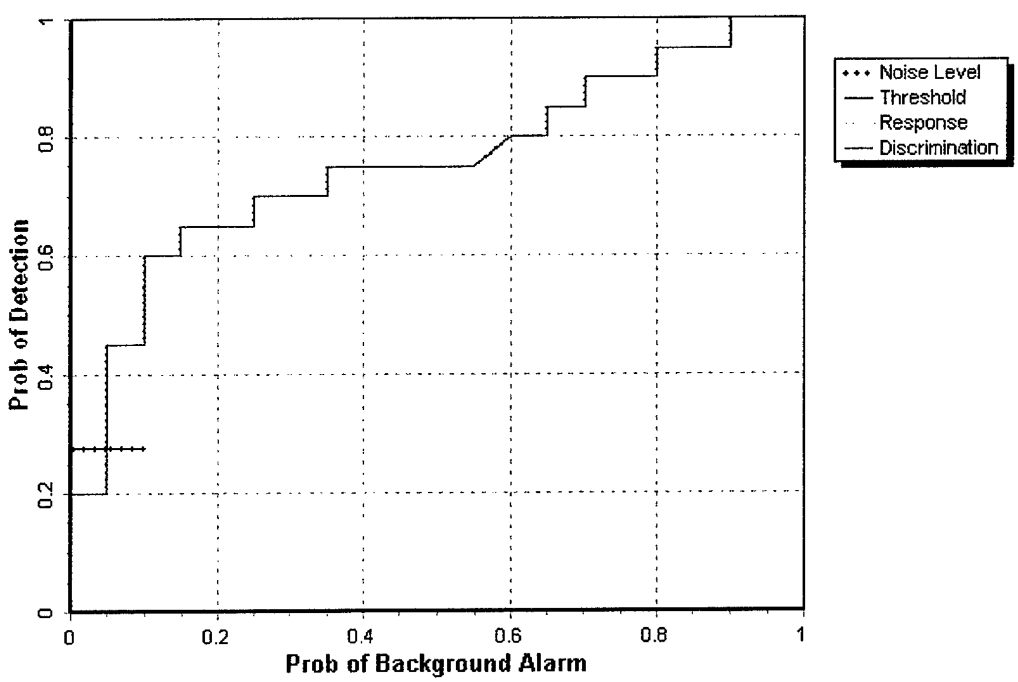

Figure 5. GEM-3 blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20 mm.

4.3 PERFORMANCE SUMMARIES

Results for the Blind Grid test, broken out by size, depth and nonstandard ordnance, are presented in Table 6. (For cost results, see section 5.) Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. (See app A for size definitions.) The results are relative to the number of ordnances emplaced. Depth is measured from the closest point of anomaly to the ground surface.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

TABLE 5. SUMMARY OF BLIND GRID RESULTS FOR MTADS

Metric	Overall	Standard	Nonstandard	By Size			By Depth, m		
				Small	Medium	Large	< 0.3	0.3 to <1	>= 1
RESPONSE STAGE									
P_d	0.25	0.30	0.15	0.20	0.25	0.30	0.40	0.15	0.00
P_d Low 90% Conf	0.18	0.23	0.06	0.13	0.16	0.12	0.28	0.06	0.00
P_{fp}	0.30	-	-	-	-	-	0.40	0.20	0.20
P_{fp} Low 90% Conf	0.24	-	-	-	-	-	0.31	0.11	0.02
P_{ba}	0.05	-	-	-	-	-	-	-	-
DISCRIMINATION STAGE									
P_d	0.25	0.30	0.15	0.20	0.25	0.30	0.40	0.15	0.00
P_d Low 90% Conf	0.18	0.23	0.06	0.13	0.16	0.12	0.28	0.06	0.00
P_{fp}	0.30	-	-	-	-	-	0.40	0.20	0.20
P_{fp} Low 90% Conf	0.24	-	-	-	-	-	0.31	0.11	0.02
P_{ba}	0.05	-	-	-	-	-	-	-	-

Response Stage Noise Level: 50.00.
Recommended Discrimination Stage Threshold: 50.00.

Note: The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

TABLE 6. EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	1.00	0.00	0.00
With No Loss of P_d	1.00	0.04	0.00

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 7). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are 20mmP, 105H, and 2.75in, respectively.

TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO

Size	% Correct
Small	0.0
Medium	0.0
Large	0.0
Overall	0.0

Note: The demonstrator did not attempt to provide type classification.

4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the Blind Grid, only depth errors are calculated, since (x, y) positions are known to be the centers of each grid square.

TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean, m	Standard Deviation, m
Depth	0.32	0.14

SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor", the second person was designated "data analyst", and the third and following personnel were considered "field support". Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity logs. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the Calibration Lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

TABLE 9. ON-SITE LABOR COSTS

	No. People	Hourly Wage	Hours	Cost
		INITIAL SETUP		
Supervisor	1	$95.00	3.25	$308.75
Data Analyst	1	57.00	3.25	185.25
Field Support	2	28.50	3.25	185.25
Subtotal				**$679.25**
		CALIBRATION		
Supervisor	1	$95.00	8.41	$798.95
Data Analyst	1	57.00	8.41	479.37
Field Support	2	28.50	8.41	479.37
Subtotal				**$1757.59**
SITE SURVEY				
Supervisor	1	$95.00	12.33	$1171.35
Data Analyst	1	57.00	12.33	702.81
Field Support	2	28.50	12.33	702.81
Subtotal				**$2576.97**

See notes at end of table.

TABLE 9 (CONT'D)

	No. People	Hourly Wage	Hours	Cost
DEMOBILIZATION				
Supervisor	1	$95.00	1.0	$95.00
Data Analyst	1	57.00	1.0	57.00
Field Support	2	28.50	1.0	28.50
Subtotal				**$180.50**
Total				**$5194.31**

Notes: Calibration time includes time spent in the Calibration Lanes as well as calibration before each data run.

Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

SECTION 6. COMPARISON OF RESULTS TO DATE

No comparisons to date.

SECTION 7. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within R_{halo} of an emplaced ordnance item.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

R_{halo}: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the projected length of the ordnance onto the ground plane plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75-inch Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-lb bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selects the threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive (P_{fp}) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive (fp^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of False Positive (P_{fp}^{res}): P_{fp}^{res} = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm: An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind Grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open Field only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{fp}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can, therefore, be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to nonordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm: An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can, therefore, be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] Figure A-1 shows how P_d versus P_{fp} and P_d versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

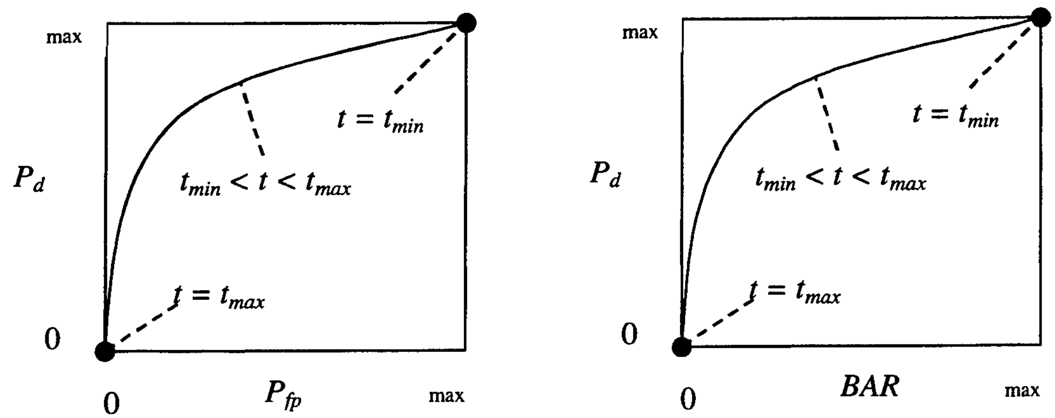

Figure A-1. ROC curves for open-field testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a predetermined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from nonordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$: measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage t_{min}) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$: measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage t_{min}). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 4).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

	Blind Grid	Open Field	Moguls
P_d^{res}	100/100 = 1.0	8/10 = .80	20/33 = .61
P_d^{disc}	80/100 = 0.80	6/10 = .60	8/33 = .24

P_d^{res}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

P_d^{disc}: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of 10 emplaced were correctly discriminated as such in open field testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{res}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

P_d^{disc}: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

APPENDIX B. DAILY WEATHER LOGS

TABLE B-1. WEATHER LOG

Weather Data from Phillips Airfield						
Date	Time, EDST	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	RH, %	Precipitation, in.
09/08/2003	00:00	61.0	61.8	60.1	97.90	0.00
09/08/2003	01:00	61.2	61.5	60.6	98.20	0.00
09/08/2003	02:00	61.0	61.5	60.4	98.10	0.00
09/08/2003	03:00	60.4	60.9	59.7	98.40	0.00
09/08/2003	04:00	59.3	60.1	58.6	98.70	0.00
09/08/2003	05:00	58.2	59.3	57.2	99.00	0.00
09/08/2003	06:00	57.4	58.6	56.4	99.20	0.00
09/08/2003	07:00	60.4	64.8	57.5	98.10	0.00
09/08/2003	08:00	68.5	71.6	64.4	84.60	0.00
09/08/2003	09:00	73.5	75.3	71.3	71.23	0.00
09/08/2003	10:00	76.6	77.7	74.9	62.32	0.00
09/08/2003	11:00	77.8	78.7	77.0	60.46	0.00
09/08/2003	12:00	79.0	80.2	78.1	59.18	0.00
09/08/2003	13:00	80.4	81.9	79.4	57.91	0.00
09/08/2003	14:00	80.6	81.8	79.8	58.38	0.00
09/08/2003	15:00	80.5	81.2	80.1	58.38	0.00
09/08/2003	16:00	80.2	81.0	79.5	60.65	0.00
09/08/2003	17:00	78.0	80.0	76.3	71.41	0.00
09/08/2003	18:00	75.7	77.5	73.6	80.40	0.00
09/08/2003	19:00	74.7	75.3	74.0	78.12	0.00
09/08/2003	20:00	74.2	75.0	73.2	79.00	0.00
09/08/2003	21:00	72.5	73.3	71.8	84.40	0.00
09/08/2003	22:00	71.6	72.6	70.4	79.33	0.00
09/08/2003	23:00	69.8	70.7	69.0	81.60	0.00
09/09/2003	00:00	68.7	69.4	67.8	83.40	0.00
09/09/2003	01:00	68.1	68.8	67.2	85.00	0.00
09/09/2003	02:00	68.3	68.9	67.5	85.00	0.00
09/09/2003	03:00	66.7	67.8	65.4	89.20	0.00
09/09/2003	04:00	65.4	65.9	64.9	91.30	0.00
09/09/2003	05:00	65.1	65.5	64.6	91.50	0.00
09/09/2003	06:00	64.8	65.2	64.5	90.80	0.00
09/09/2003	07:00	65.9	67.0	64.6	88.30	0.00
09/09/2003	08:00	67.8	69.5	66.3	83.40	0.00
09/09/2003	09:00	70.1	71.7	69.0	70.97	0.00

TABLE B-1 (CONT'D)

Weather Data from Phillips Airfield						
Date	Time, EDST	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	RH, %	Precipitation, in.
09/09/2003	10:00	72.2	73.0	71.1	54.28	0.00
09/09/2003	11:00	73.0	73.9	72.5	50.62	0.00
09/09/2003	12:00	73.7	74.6	72.8	54.56	0.00
09/09/2003	13:00	74.6	75.5	73.9	54.94	0.00
09/09/2003	14:00	75.3	76.2	74.2	51.99	0.00
09/09/2003	15:00	75.0	75.5	74.2	51.57	0.00
09/09/2003	16:00	74.2	74.8	73.6	51.04	0.00
09/09/2003	17:00	73.3	74.1	72.3	52.62	0.00
09/09/2003	18:00	71.3	72.7	69.6	55.50	0.00
09/09/2003	19:00	68.7	70.0	67.6	58.99	0.00
09/09/2003	20:00	67.0	68.2	66.0	60.90	0.00
09/09/2003	21:00	65.3	66.5	64.5	67.22	0.00
09/09/2003	22:00	64.3	65.1	62.6	71.86	0.00
09/09/2003	23:00	62.4	63.9	60.4	78.16	0.00
09/10/2003	00:00	59.7	60.7	58.6	84.10	0.00
09/10/2003	01:00	58.3	59.0	57.6	88.80	0.00
09/10/2003	02:00	57.1	58.2	56.3	92.90	0.00
09/10/2003	03:00	56.9	57.5	56.5	93.50	0.00
09/10/2003	04:00	57.4	58.2	56.6	92.00	0.00
09/10/2003	05:00	56.3	57.0	55.7	93.90	0.00
09/10/2003	06:00	55.7	56.3	55.0	95.40	0.00
09/10/2003	07:00	58.1	60.8	55.3	91.90	0.00
09/10/2003	08:00	62.6	65.2	60.5	83.20	0.00
09/10/2003	09:00	66.0	67.3	64.8	75.33	0.00
09/10/2003	10:00	67.7	70.2	66.3	70.47	0.00
09/10/2003	11:00	70.7	72.0	69.0	64.24	0.00
09/10/2003	12:00	71.3	73.4	69.0	61.69	0.00
09/10/2003	13:00	72.3	74.6	70.6	58.95	0.00
09/10/2003	14:00	74.0	75.2	72.7	54.73	0.00
09/10/2003	15:00	74.9	75.9	74.0	52.57	0.00
09/10/2003	16:00	75.5	76.2	74.6	50.60	0.00
09/10/2003	17:00	75.8	76.6	74.9	49.73	0.00
09/10/2003	18:00	73.8	75.3	71.2	55.60	0.00
09/10/2003	19:00	66.8	71.6	63.6	75.62	0.00
09/10/2003	20:00	62.7	64.3	61.4	88.00	0.00
09/10/2003	21:00	60.5	61.9	59.4	93.50	0.00
09/10/2003	22:00	59.0	60.1	58.4	95.20	0.00

TABLE B-1 (CONT'D)

Weather Data from Phillips Airfield						
Date	Time, EDST	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	RH, %	Precipitation, in.
09/10/2003	23:00	58.5	59.1	58.1	95.90	0.00
09/11/2003	00:00	57.2	58.4	56.6	96.90	0.00
09/11/2003	01:00	56.5	57.2	55.6	98.00	0.00
09/11/2003	02:00	56.1	56.6	55.7	97.30	0.00
09/11/2003	03:00	58.7	61.6	55.8	91.80	0.00
09/11/2003	04:00	58.0	60.8	56.3	91.90	0.00
09/11/2003	05:00	58.2	60.1	56.9	93.20	0.00
09/11/2003	06:00	57.2	58.8	55.9	93.80	0.00
09/11/2003	07:00	59.1	63.2	56.5	89.70	0.00
09/11/2003	08:00	65.8	68.7	63.0	74.54	0.00
09/11/2003	09:00	70.4	71.8	68.5	65.84	0.00
09/11/2003	10:00	72.9	74.0	71.7	60.09	0.00
09/11/2003	11:00	74.5	75.7	73.4	56.62	0.00
09/11/2003	12:00	76.6	77.6	75.2	53.00	0.00
09/11/2003	13:00	77.9	79.0	77.2	48.50	0.00
09/11/2003	14:00	78.8	79.6	77.9	46.95	0.00
09/11/2003	15:00	79.4	80.0	78.8	48.09	0.00
09/11/2003	16:00	79.5	80.0	79.0	49.18	0.00
09/11/2003	17:00	78.9	79.6	78.2	52.35	0.00
09/11/2003	18:00	76.9	78.5	74.9	54.67	0.00
09/11/2003	19:00	72.8	75.5	69.6	62.78	0.00
09/11/2003	20:00	69.3	70.6	67.6	69.00	0.00
09/11/2003	21:00	68.1	70.0	67.0	71.02	0.00
09/11/2003	22:00	68.8	69.5	67.4	67.03	0.00
09/11/2003	23:00	68.5	69.4	68.0	65.01	0.00
09/12/2003	00:00	68.0	68.6	67.2	68.17	0.00
09/12/2003	01:00	67.2	68.0	66.6	76.66	0.00
09/12/2003	02:00	66.5	67.1	66.0	83.30	0.00
09/12/2003	03:00	66.3	66.8	65.8	85.50	0.00
09/12/2003	04:00	66.0	66.5	65.3	85.00	0.00
09/12/2003	05:00	65.6	66.2	65.1	85.20	0.00
09/12/2003	06:00	65.1	65.6	64.6	87.00	0.00
09/12/2003	07:00	65.4	66.1	64.9	87.10	0.00
09/12/2003	08:00	66.1	66.7	65.8	83.80	0.00
09/12/2003	09:00	67.2	68.0	66.4	78.45	0.00

TABLE B-1 (CONT'D)

Weather Data from Phillips Airfield						
Date	Time, EDST	Average Temperature, °F	Maximum Temperature, °F	Minimum Temperature, °F	RH, %	Precipitation, in.
09/12/2003	10:00	67.7	68.2	67.4	74.80	0.00
09/12/2003	11:00	68.2	69.3	67.6	72.55	0.00
09/12/2003	12:00	69.6	70.2	68.8	67.15	0.00
09/12/2003	13:00	67.4	69.0	64.7	68.94	0.00
09/12/2003	14:00	63.1	65.1	62.0	89.10	0.16
09/12/2003	15:00	62.7	63.3	62.0	94.10	0.13
09/12/2003	16:00	62.5	63.4	61.8	95.40	0.04
09/12/2003	17:00	63.7	64.4	63.1	94.70	0.06
09/12/2003	18:00	64.2	64.5	63.8	94.10	0.00
09/12/2003	19:00	64.6	65.2	64.2	93.10	0.00
09/12/2003	20:00	64.9	65.2	64.5	93.90	0.02
09/12/2003	21:00	65.1	65.7	64.7	94.60	0.01
09/12/2003	22:00	65.7	66.1	65.1	94.60	0.13
09/12/2003	23:00	65.8	66.4	65.3	95.60	0.00

APPENDIX C. SOIL MOISTURE

Daily Soil Moisture Logs

Demonstrator: ERDC
Date: 9 September 2003
Times: 0730 hours (AM), 1215 hours (PM)

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	40.3	40.2
	6 to 12	38.5	38.5
	12 to 24	9.2	9.3
	24 to 36	6.3	6.5
	36 to 48	6.9	7.3

Demonstrator: ERDC
Date: 10 September 2003
Times: 0730 hours (AM), 1210 hours (PM)

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	39.8	39.7
	6 to 12	38.0	37.9
	12 to 24	9.0	8.8
	24 to 36	5.7	5.7
	36 to 48	5.9	5.4

Demonstrator: ERDC
Date: 11 September 2003
Times: 0730 hours (AM), 1215 hours (PM)

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No readings taken	No readings taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	39.8	39.7
	6 to 12	38.5	38.5
	12 to 24	7.9	7.8
	24 to 36	5.1	5.0
	36 to 48	4.9	4.8

Demonstrator: ERDC
Date: 12 September 2003
Times: 0836 hours (AM), 1215 hours (PM)

Probe Location	Layer, in.	AM Reading, %	PM Reading, %
Wet Area	0 to 6	No Readings Taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Wooded Area	0 to 6	No readings taken	No Readings Taken
	6 to 12		
	12 to 24		
	24 to 36		
	36 to 48		
Open Area	0 to 6	39.5	39.5
	6 to 12	37.7	37.5
	12 to 24	7.8	7.9
	24 to 36	4.5	4.5
	36 to 48	4.6	4.4

APPENDIX D. DAILY LOGS

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
						ERDC GEM-3						
9/8/2003	4	CALIBRATION LANE	1100	1215	75	INITIAL MOBILIZATION	INITIAL MOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY
9/8/2003	4	CALIBRATION LANE	1215	1330	75	BREAK/LUNCH	BREAK/LUNCH	GPS	NA	LINEAR	SUNNY	MUDDY
9/8/2003	4	CALIBRATION LANE	1330	1530	120	INITIAL MOBILIZATION	INITIAL MOBILIZATION	GPS	NA	LINEAR	SUNNY	MUDDY
9/8/2003	4	CALIBRATION LANE	1530	1545	15	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1330	1340	10	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1340	1420	40	DAILY START/STOP	SET UP METERING TAPES	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1420	1525	65	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1525	1535	10	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1535	1615	40	EQUIPMENT FAILURE	WHEEL BOLT BROKE OFF, REPLACED	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1615	1640	25	DOWNTIME MAINTENANCE CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1640	1700	20	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1700	1705	5	EQUIPMENT FAILURE	WHEEL BOLT BROKE OFF, REPLACED	GPS	NA	LINEAR	SUNNY	MUDDY
9/9/2003	4	CALIBRATION LANE	1705	1715	10	DAILY START/STOP	END OF DAILY OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	0845	0900	15	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	0900	0930	30	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	0930	1000	30	EQUIPMENT FAILURE	WHEEL BOLT BROKE OFF	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1000	1015	15	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
9/10/2003	4	CALIBRATION LANE	1015	1030	15	DOWNTIME MAINTENANCE CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1030	1100	30	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1100	1115	15	EQUIPMENT FAILURE	WHEEL BOLT BROKE OFF, REPLACED	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1115	1130	15	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1130	1145	15	DOWNTIME MAINTENANCE CHECK	DATA CHECK	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1145	1230	45	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1230	1340	70	BREAK/LUNCH	BREAK/LUNCH	GPS	NA	LINEAR	SUNNY	MUDDY
9/10/2003	4	CALIBRATION LANE	1340	1420	40	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	SUNNY	MUDDY
9/11/2003	4	BLIND TEST GRID	0810	0840	30	DAILY START/STOP	START OF DAILY OPERATIONS	GPS	NA	LINEAR	SUNNY	MUDDY
9/11/2003	4	BLIND TEST GRID	0840	1200	200	EQUIPMENT FAILURE	BAD CABLE CONNECTION, SODERED CABLE	GPS	NA	LINEAR	SUNNY	MUDDY
9/11/2003	4	BLIND TEST GRID	1200	1315	75	BREAK/LUNCH	BREAK/LUNCH	GPS	NA	LINEAR	SUNNY	MUDDY
9/11/2003	4	BLIND TEST GRID	1315	1445	90	EQUIPMENT FAILURE	BAD CABLE CONNECTION, SODERED CABLE	GPS	NA	LINEAR	SUNNY	MUDDY
9/12/2003	4	BLIND TEST GRID	0945	1015	60	DAILY START/STOP	CHANGE SENSOR HEAD	GPS	NA	LINEAR	CLOUDY	RAINY
9/12/2003	4	BLIND TEST GRID	1015	1025	10	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	RAINY
9/12/2003	4	BLIND TEST GRID	1025	1330	115	EQUIPMENT FAILURE	BAD CABLE CONNECTION, SODERED CABLE	GPS	NA	LINEAR	CLOUDY	
9/12/2003	4	BLIND TEST GRID	1330	1430	60	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	

Date	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min	Operational Status	Operational Status - Comments	Track Method	Track Method=Other Explain	Pattern	Field Conditions	
9/12/2003	4	BLIND TEST GRID	1430	1515	45	WEATHER	HEAVY RAIN	GPS	NA	LINEAR	CLOUDY	RAINY
9/12/2003	4	BLIND TEST GRID	1515	1600	45	COLLECT DATA	COLLECT DATA	GPS	NA	LINEAR	CLOUDY	RAINY
9/12/2003	4	BLIND TEST GRID	1600	1700	60	DEMOBILIZATION	DEMOBILIZATION	GPS	NA	LINEAR	CLOUDY	RAINY

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, pages 144 through 151.

APPENDIX F. ABBREVIATIONS

A/D	=	analog to digital
AEC	=	U.S. Army Environmental Center
APG	=	Aberdeen Proving Ground
ATC	=	U.S. Army Aberdeen Test Center
EMI	=	electromagnetic induction
EMIS	=	Electromagnetic Induction Spectroscopy
ERDC	=	U.S. Army Corp of Engineers Engineering, Research and Development Center
ESTCP	=	Environmental Security Technology Certification Program
EQT	=	Army Environmental Quality Technology Program
GPS	=	Global Positioning System
JPG	=	Jefferson Proving Ground
LCD	=	liquid crystal display
POC	=	point of contact
QA	=	quality assurance
QC	=	quality control
ROC	=	receiver-operating characteristic
RTK	=	real-time kinematic
SERDP	=	Strategic Environmental Research and Development Program
UXO	=	unexploded ordnance
YPG	=	U.S. Army Yuma Proving Ground

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